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For: METHODS AND ARTICLES FOR DETECTING, VERIFYING, AND REPAIRING COLLINEARITY IN A MODEL OR SUBSETS OF A MODEL

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REQUEST FOR CORRECTED PUBLICATION PURSUANT TO 37 C.F.R. 1.221(b)

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Sir:

Pursuant to 37 C.F.R. 1.221(b), we hereby request republication of the above-referenced patent application, which was published as U.S. 2006/0015194-A9 on January 19, 2006, due to the following material mistakes:

In the last line of paragraph [0066] on page 5, "$t = 1,\ldots,p$, $q \approx t$" should be replaced with "$t = 1,\ldots,p$, $q \neq t$". The correct version appears on page 13, line 24 of the specification as filed.

Enclosed are a copy of the relevant page of the publication with changes noted in red.

Please note that this request is being filed within the two month period allowed.

Since the mistakes were made by the U.S. Patent and Trademark Office and not by Applicants or Applicants' Attorney/Agent, it is understood that there are no additional fees for the requested republication.

Respectfully submitted,

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-continued

$$\sigma_{ij}^{-}(sm) =< \sum_{k=1}^{m(sm)} \sum_{l=1}^{m(sm)} g_{lk}(sm) * u_{li}(sm) * v_{kj}(sm) <= \sigma_{ij}^{+}(sm) \qquad \text{Constraint 10.2}$$

$$i,j=1, \ldots, m(sm),\ sm=1, \ldots, p$$

G(0) represents the nominal model, G^{+} and G^{-} represent the allowed upper and lower bound of the model. σ_{ij}^{-} and σ_{ij}^{+} are allowed upper and lower bound for the singular values. m(sm) is the dimension of the sub-matrix sm. p is the total number of nearly collinear sub-matrices $G_{nc}(sm)$.

[0056] Equation 10 is the objective function. The objective function minimizes deviation from the nominal model as long as the required perfect collinearlity can be achieved. Constraint 10.1 represents the allowed variation for each model element. Constraint 10.2 is contributed from each nearly collinear sub-matrix. All $u_{li}(sm)$ and $v_{li}(sm)$ are the singular vectors calculated from the original sub-matrix $G_{nc}(sm)$, and hence the same directionality is always maintained.

[0057] In some embodiments, σ_{ij}^{-} and σ_{ij}^{+} are set to

[0058] 1) $\sigma_{ij}^{-}(sm)=\sigma_{ij}^{+}(sm)=0$ if $i \approx j$, which corresponds to the off-diagonal portion of the singular value matrix;

[0059] 2) $\sigma_{ii}^{-}(sm)=\sigma_{ii}^{+}(sm)=0$ if $i>r(sm)$, which corresponds to those small singular values to be zeroed out;

[0060] 3) $\sigma_{ii}^{-}(sm)=\sigma_{i}(0)*(1-eps)$ and $\sigma_{ii}^{+}(sm)=\sigma_{i}(0)*(1+eps)$ if $i <= r(sm)$, where $0<eps<1$ is a constant. Choosing a large value for eps allows large variations in the singular values. Since the objective function always tries to find the minimal variation for the model matrix, it is expected that variation of the singular value will also be very mild. Hence, a small eps (for instance, eps=0.1) can be safely used.

[0061] Finally, Equation 10 is a standard QP formula and can be solved globally and efficiently.

Uncollinearization

[0062] If the process is not collinear, or is nearly collinear but needs the controller to fully explore its capability, then adjustments to the model can be made to improve the condition number so that an improved robustness can be achieved.

[0063] Uncollinearization should satisfy the following requirements:

[0064] 1. The repaired model should have the same directionality as the original model because changing the direction can cause unwanted control problems that can potentially result in a less desirable performance than with the original collinearity.

[0065] 2. The directionality change should be made within allowed ranges. Additional restrictions can also be imposed, such as additional linear equality or inequality constraints.

[0066] 3. When treating a model matrix larger than 2×2, a collinear sub-matrix can share common elements with another collinear sub-matrix. Such a case can result in a "zigzag game" or never ending loop, with repairs to one sub-matrix giving rise to a need for repairs to the other sub-matrix. Hence, the methodology should be able to deal with multiple sub-matrices in a synchronized way.

To achieve these goals, the following optimization formula was created:

$$\text{Maximize} \sum_{sm=1}^{p} \sum_{i=1}^{m(sm)-r(sm)} (\sigma_{r(sm)+i} / \sigma_{r(sm)+i}(0))^2 \qquad \text{Equation 11}$$

subject to:

$$g_{ij}^{+}(sm) =< \sum_{k=1}^{m(sm)} \sigma_k(sm) * u_{ik}(sm) * v_{jk}(sm) <= g_{ij}^{-}(sm), \qquad \text{Constraint 11.1}$$

$$i,\ j = 1, \ldots, m(ms)$$

$$\sigma_i^{-}(sm) =< \sigma_i(sm) <= \sigma_i^{+}(sm),\ i = 1, \ldots, m(sm) \qquad \text{Constraint 11.2}$$

$$\sum_{k=1}^{m(q)} \sigma_k(q) * u_{ik}(q) * v_{jk}(q) = \sum_{k=1}^{m(t)} \sigma_k(t) * u_{ik}(t) * v_{jk}(t), \qquad \text{Constraint 11.3}$$

for those i,j which point to the same element in G, sm, q, ~~t=1, . . . , p, q=t.~~
t=1, . . . , p, q ≠ t.

[0067] g_{ij}^{+} and g_{ij}^{-} denote the upper and lower bounds of the allowed model adjustment, σ_i^{-} and σ_i^{+} are upper and lower bounds on the singular values, $\sigma_{r+i}(0)$ represents the original singular value, and m(sm) is the dimension of the sub-matrix sm. p is the total number of nearly collinear sub-matrices $G_{nc}(sm)$. Additional explanation of Equation 11 is provided below.

[0068] The objective function is to maximize the portion of the smaller singular values of all nearly collinear sub-matrices. The weighting factor, $1/\sigma_{r(sm)+i}(0)$, means the smaller the original singular value, the more improvement the optimizer will attempt to obtain. Constraint 11.1 represents the allowed variation for each model element. All $u_{ik}(sm)$ and $v_{jk}(sm)$ (as well as $u_{ik}(q)$, $v_{jk}(q)$, $u_{ik}(t)$, and $v_{jk}(t)$) are the singular vectors calculated from the original sub-matrix $G_{nc}(sm)$ (or $G_{nc}(q)$, $G_{nc}(t)$), and hence the same directionality is always maintained. Constraint 11.2 is the allowed singular value variation range, which is discussed further below.

[0069] Constraint 11.3 is needed if there are two sub-matrices who share the same element in the original model matrix. In this case, any adjustment made for one sub-matrix will automatically be coordinated with another associated sub-matrix, and hence remove the "zigzag problem."

[0070] The final goal is to maximize the condition number. Equation 11 does not explicitly employ a condition number because directly optimizing a condition number will pose a computation problem so difficult as to be unrealistic. As such, an approximation is made by maximizing the portion of the smaller singular values, while keeping the other singular values from dropping too low. For this purpose, the bounds for each singular value should be set as follows: